The Use of Biomedical Imaging for Computer-Aided Diagnosis and Treatment Planning in Orthodontics and Dentofacial Orthopedics

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Abstract: - Orthodontics and Dentofacial Orthopedics, the most complex branch of dentistry, assume a careful acquisition and interpretation of a large amount of information to achieve a correct diagnosis and treatment planning. Medical imaging has become a major tool in almost every aspect of orthodontic practice, research and education. Three-dimensional imaging had a great evolution in recent years and has found various applications in orthodontics as well as in oral and maxillofacial surgery. The paper will present the most recent uses of biomedical imaging in the orthodontic practice. Digital photographs, digital models, digital radiology and cone beam computed tomography will be presented and evaluated. We outlined the specific clinical problems where this digital technology can best help the orthodontist in providing improved diagnosis and treatment planning. The specialists from dental medicine are encouraged to exploit the potential of this technology and to contribute to the development of these powerful diagnostic tools.

Key-Words: - three-dimensional imaging, orthodontics, dentofacial orthopedics, diagnostic tools, digital technology, medical imaging, digital photography, digital models, digital radiology

1 Introduction

The evolution of orthodontics and dentofacial orthopedics and learning about the location of malocclusions at different levels of the stomatognathic system led to a more accurate diagnosis and a more effective treatment plan. But just this multiple localization makes diagnosis in orthodontics to be extremely difficult because you have to consider many parameters that characterize the different involved structures.

In addition the adult orthodontic treatment, a direction in continuous development, requires a broad interdisciplinary collaboration between Orthodontics, Maxillofacial Surgery, Periodontics, Prosthodontics and Implantology [1, 2].

Within this collaboration an enormous amount of information from each of the involved specialty is presented, analyzed and evaluated. No effective therapy is possible walking with the X-rays, photographs or models from one specialist to another. All these problems have found solutions in the present digital age with Computer-Aided Diagnosis (CAD) and treatment planning.

The 21st century will be the digital era of dental imaging much as film imaging dominated the 20th century [3].

Computer-Aided Diagnosis involves the use of imaging techniques and image processing tools. Biomedical Imaging is one of the most dynamic development directions between medicine and computer science and involves the creation of images of the human body for clinical, medical or scientific purposes.

Medical imaging has become a major tool in almost every aspect of orthodontic practice, research and education [4].

Today the evolution of digital technology has changed computers from having a limited, supporting role mainly in managing databases to one being indispensable in orthodontic treatment [5].

Three-dimensional imaging and computer science had a great evolution in recent years and has
found various applications in orthodontics as well as in oral and maxillofacial surgery [6].

2 Problem Formulation

The paper will present the most recent uses of biomedical imaging in the orthodontic practice. Digital photographs, digital models, digital radiology and cone beam computed tomography will be presented and evaluated. We outlined the specific clinical problems where this digital technology can best help the orthodontist in providing improved diagnosis and treatment planning.

3 Problem Solution

For each orthodontic treated case the digital images were obtained using different devices as digital camera, study model scanner, digital radiology and the new Galileos cone beam technology. The dedicated software that we use for analyze and measurements is OnyxCeph™ developed by the Firma Image Instruments Gmbh, Germany. It has a user-friendly interface, allows easy acquisition of biomedical images, including the more specific .stl extension which is typically for the digital models and has many features that help to identify and measure various orthodontic parameters.

All measurement, simulation and image processing tools available in OnyxCeph™ merely serve to assist you in finding a diagnosis [7]. To achieve exact measurements we have to obtain digital images in the focal plane without distortion. This has to be secured by means of appropriate calibration of the image, acquisition process or suitable correction of the digitally recorded images [7].

In digital frontal and lateral photographs the software helps in establishing the exact position of the different anthropometric landmarks depending on the chosen facial analysis (Fig.1).

Fig.1 Frontal and lateral digital photograph of a patient analyzed with OnyxCeph™

In order to have precise photographic measurements the photographic technique has to be standardized [8]. The exact technique that we used was described in previously published papers [8, 9, and 10]. We are encouraged to use this digital photographic standardized technique because it is complex, fast and easy to be reproduced as many times it is needed [8].

Intraoral digital photographs analyzed with this software allow revealing subtle aspects and changes during the treatment that are not observed during the clinical examination (Fig.2).

Fig.2 Intraoral digital photograph

Digital models, a true revolution in orthodontic diagnosis, allow through evaluation of medical images obtained by scanning to achieve the most detailed dimensional analysis (Fig.3).

Fig. 3 Analysis of a digital model with the dedicated software

The software through various digital tools like manipulation of the display, 3D rotation of the model or image enhancement enables accurate marking of the odontometric points. Subsequently according to the chosen model analyze (they are 16 analysis like Bolton-Anterior, Bolton-Overall, Korkhaus, Linder Harth, Lundstroem, Muehlberg, Pont Index, Supporting Zones, Tonn or Weise) the program offers the most detailed metric characterization of the dento-alveolar arches.

The introduction of digital models has provided the orthodontist with a viable alternative to plaster models with the added advantages of
electronic storage of data, minimal storage required, simple and accurate cataloguing and a rapid transmission of records for consultation [11].

3D databases from digital models and virtual model analysis are useful tools for the diagnosis and treatment planning but also for education and research, facilitating statistical analysis [5].

Digital panoramic radiographs allow a detailed highlighting of all involved anatomical structure and an evaluation of the development stage of the teeth to determine accurate the dental age (Fig.4).

Landmark identification is by far the most difficult task in the analysis of cephalometric images. The OnyxCeph™ software helps in this regard in several ways. At each cephalometric landmark it appears its definition (audio and visual) and it positioning on a schematic tracing sketch (Fig.5).

The software offers a lot of specific tools like brightness/contrast controller, magnifier, histogram equalization, correct brightness, invert image, gray scale, smooth image, sharpen, accentuate structures and relief in order to adjust the medical image to make it easier to analyze or improve its visual quality. Histogram equalization, a method from image processing, can emphasize the local contrast leading to better view of bone contour (Fig.6).

Also for enhancement of the investigated structures you can use the magnifier tool that creates a temporary enlargement of the selected medical image for better highlighting of the landmark (Fig.7).

After placement of all the requested landmarks (depending on the chosen analysis) and correct calibration, the software will draw on the cephalograms all the angles and distances used for evaluation and calculation (Fig.8).
Fig. 8 Lateral cephalogram with landmarks, angles and distances

The following changes can be applied to the analyzed image: image visible/invisible, tracing visible/invisible, templates visible/invisible, points visible/invisible, show point name at mouse position (Fig. 9).

Fig. 9 Invisible image for better visualization of the results

After choosing one of the 30 analyses the program will generate a table that includes: variable, description, clinical norm, value (determined), difference, deviation and verbal appreciation (Fig. 10).

Fig. 10 The final chart of the Schmuth analyze

Using biomedical imaging and adequate software we can simulate the orthodontic movements and the effects of orthognathic surgery on the involved structures (Fig. 11). This facilitates communication between doctor and patient in highlighting the final results of the therapeutic approach.

Fig. 11 Simulation of the orthodontic movements

Many of the techniques developed for biomedical imaging have beside the medical applications scientific and industrial applications. Digital devices in conjunction with CAD-CAM technologies can be used in many fields of dentistry, in individualization and repair of orthodontic appliances [15-18].

The greatest evolution in the field of biomedical imaging use in dentistry was achieved by the introduction of the technology referred as CBCT (cone beam computed tomography).

This imaging modality eliminates the shortcomings of 2-D imaging, produces a smaller radiation dose than that produced by medical CT and enables clinicians to make more accurate treatment planning decisions, which can lead to more successful surgical procedures [19,20].

As the source and receptor rotate once around the patient, many exposures are made, ranging in duration between 8.9 and 40 seconds. The software “reconstructs” the sum of the exposures via algorithms specified by the manufacturer into as many as 512 axial slice images. These images are in Digital Imaging and Communications in Medicine (DICOM) data format. DICOM is standard for handling, storing, printing and transmitting information in medical imaging [20, 21].

One advantage of using a DICOM data format is that the dentist can make precise measurements in any plane within the viewing software [20].

For our patients we use the new GALILEOS cone beam technology (Sirona Dental Systems, Inc.). It has an optimal combination of hardware and software (GALAXIS 3D imaging software) providing good information for 3D diagnosis and 3D volume reconstructions (Fig. 12).
4 Conclusion
With this modern biomedical imaging devices orthodontics and dentofacial orthopedics moves into a new era of diagnosing, documenting and communication. In this new environment the orthodontist, oral surgeon, implantologist and restorative dentist can better communicate and improve their therapeutic success.

The specialists from dental medicine are encouraged to exploit the potential of this technology and to contribute to the development of these powerful diagnostic tools.

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